A 24 GHz beacon source using IQ upconversion

Andy Talbot   G4JNT
White Box Modules

- Drive is LO/2 to a pair of Subharmonic mixers
  - Internal Doubler for drive at 6GHz
- Quadrature image cancelling mixer at 24GHz
- 90° Hybrid at ~700MHz
- Remove the hybrid and go direct to diodes
A Very Simple Solution

- DC Through diodes just controls level
- ON-OFF with ramping
- Wasteful, throws away the image cancelling capability
Basband upconvert

• Direct Basband drive to diodes, I/Q folded spectrum
  • (third method SSB generation)
• Quadrature audio DDS, analogue allpass OPAmps, or DSPIC
• OPAMPs need to present a 50Ω source, but only have to supply <1.5V pk-pk drive. So NE553x opamps and resistors work FB.

• Need to generate exact centre frequency for LO
Frequency Setting

• No scope for fiddling with centre frequency using Direct U/C.

• So we must use a Fract-N synth or sit on a wide spaced grid
  • Fract-N at 24GHz is potentially going to be a bit noisy and spurious-ridden
  • And has to generate at 6GHz

• ADF5355 is an off the shelf solution, but as I only had one of those and didn’t want to dedicate it to a beacon, what other options were there?
Low IF With Integer-N synth

- How about a DDS for full frequency agility, upconverted using image reject.
- Band 24 to 24.05 is amateur primary – so image leakage on the low side is unlikely to be an issue
  - It’s not as if there are many users down there!
- Keep the numbers simple – 24040MHz LO,
  - LTC6946-3 Integer-N Synth at 6010MHz with 10MHz OCXO (High $F_{comp}$)
- 8.xx MHz drive from DDS
  - 20MHz TCXO clock for a ‘few Hz’ accuracy.
- Image < -25dBc at ~24031MHz
90 Degree Hybrid

Centre Freq 8.5MHz
Useful Bandwidth 500kHz
DDS Source

• AD9852 Module already to hand.
• Plenty of PIC firmware for all data modes
• Offers frequency and amplitude variation

• -4dBm output
• Max drive to diodes is around +12dBm each.
Gain Block

• Diodes need max +12dBm each
• Quad network has -6dB each channel
• So hybrid needs 18 – 19dBm drive

• -4dBm from DDS
• BGA6489 MMIC

• Not intended for this low frequency, but it works!
  • +20dBm $P_{1dB}$
  • > 23dB gain

• Plenty of gain margin
RF Power Amp

- 400mW (ish) Module from µWave Roundtable
- Self contained SMPSU with 12V input
Power Supply

- All modules apart from PA run from nominal 5V
  - 5.2V for WB converter
- First thoughts, 12V to 5.2V buck converter.
- Couldn’t get it clean enough, as the 5V goes direct to RF circuitry.
- Two linear converters, LM317 for 5.2V and LM7805 supplied from buck converter to 7.7V
  - Good filtering in dedicated screened box with feed-throughs.
- Total current consumption 1.6A at 13V with OCXO stabilised
- 20 Watts of heat generated
Cooling

• Traditional solution, metal box with heatsink
  • Waterproofing nightmare

• Plastic box for waterproofing, $\sim 20\text{W/K}$ across thickness, insignificant

• All modules mounted on thick Al baseplate to share heat dissipation

• Fan inside rapidly circulates air

• All the box surfaces work as heatsink $0.27\text{m}^2$

• After several hours in summer temperature indoors, surface of plastic box is about 10 - 15 deg above ambient

• Hottest items inside sit at around 45C
Antenna

• Omni would be nice, but slotted waveguide at 24GHz is not easy.
• H-plane Sectoral Horn is next best compromise
• 9dBi, 20deg vertical beamwidth, wide azimuth

• G8AGN Horn design software
  • Latest ‘JNT version for Windows
  • Gives cutting templates
Antenna

Dimensions (mm):
- 4.3
- 28.1
- 89.5
- 30.0
- 10.7

Half Cutting Template (X, Y) Coordinates (mm):
- Minimum sheet size: 90 x 37

H Plane Sectoral 24.06 GHz VSWR 3.0 Gain 3.0 dB E plane Beamwidth ~ 26°
Modulation

- As this is a sort of ad-hoc setup-and-drive-out beacon with no GPS ...
- For once, and completely contra to normal ‘JNT-think ...
- An audio modulation rather than digital mode is called-for
- And just plain CW will never be an option

- Reprogramme the DDS with 3Hz increment every 0.8ms generates a sweep. Reset after 700 steps gives 2100Hz chirp every 0.56s
- And... might as well ... a CW ident, using raised-cosine ramp.
  - Spot the phase noise and AGC pumping
Results

• At 24028.5 MHz  Opposite sideband leakage, -25dBc
• At 24048.8 MHz best value -32dBc
• No trimming of I/Q paths; no doubt that could be improved

• Some close-in DDS spurii around -60dBc
  • Changes rapidly with the sweep
• No other spurii from synth
• Mounted on my mast, I can receive it at Cheesefoot Head 5/9
Cheesefoot Head

A view from behind.

02:00
12 Aug 2017